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The Future of Nutrition Research

The ultimate question concerning a particular nutrient in our food supply is: How can we be sure we are getting the right amount at the proper time to ensure

optimum health and vitality? Because the availability of a vitamin or mineral to our bodies hinges on its interaction with other components in the diet, we in human nutrition research are seeking to understand how these interactions can limit or enhance the benefits of a particular nutrient.

For example, in some developing countries a dreadful zinc deficiency can slow the maturity of males so that in severe cases 20-year-old men look like 7-year-old boys. This deficiency occurs despite a zinc intake that is about twice that of people in the United States. In this situation, the zinc is interacting with one or more dietary factors, probably phytate or fiber, that make it largely unavailable.

In the United States, the bioavailability of calcium is controlled by other dietary factors. A high intake of protein was shown to reduce the retention of calcium by the kidneys. It was thought that the more protein you ate, the more calcium you excreted, therefore the more calcium you needed in your diet. Then someone discovered that this was more than a two-way interaction; phosphorus also gets involved. A major and very pleasant source of dietary protein—meat—contains so much phosphorus that it counteracts the negative protein effect.

We know hundreds of interactions exist among nutrients, but so far scientists can quantitatively describe only one—the interaction between iron and vitamin C. Vitamin C and an unknown factor in meat, poultry, and fish, called the “meat factor,” each enhance the bioavailability of dietary iron. But even here, we do not yet completely understand how this works.

The future of nutrition research is in the study of interactions such as these. According to calculations by D. Mark Hegsted, professor emeritus, Harvard Medical School, and a former administrator of human nutrition research for USDA, the task will be a difficult and expensive one.

To study a three-way interaction, such as the calcium-protein-phosphorus one, a scientist would need to use a minimum of 1,250 laboratory rats for a single experiment. We know of many interactions involving more than three nutrients, particularly with trace elements. Theoretically, there could be 10-way interactions, requiring as many as a 100 million rats for a single nutrition experiment.

As long as we do not fully understand these interactions, it is very risky for us to recommend supplementing diets with any one nutrient. Even those nutrients which we consider essential, such as calcium or iron, can do a lot of damage when the balance is not right.

Nutrition research is also entering another era—perhaps in part the result of the 1982 report of the Diet, Nutrition, and Cancer committee of the National Academy of Sciences that for the first time established a scientifically founded, credible hypothesis that nutrition status is a major factor in prevention of a disease as dreaded as cancer.

We now have a basis for asking: What does nutrition status do to minimize disease risk? This does not mean minimize disease or prevent disease or cure disease in any one individual. It means reduce disease overall in the population by reducing risk factors.

The Agricultural Research Service is increasingly involved in human studies to determine how much of a vitamin or mineral, fiber, or fat leads to the least risk for the two major killers—heart disease and cancer.

Besides preventing the emotional and physical suffering connected with these diseases, a successful program to improve the nutrient status of the U.S. population should reduce the need for medical care.

In 1984, the cost of drugs, medical supplies, and professional health services was estimated at \$372 billion, nearly equal to the amount spent on food at the retail level.

Walter Mertz, Director

Beltsville Human Nutrition Research Center



Agricultural Research

Cover: Aboard the freighter *Balsa 25*, entomologist James Leesch (left) and chemist Rick Simonatis place aluminum phosphide tablets into a shipment of bulk wood chips loaded in the ship's hold. Agricultural Research Service scientists are developing new techniques for controlling pests in commodities bound for foreign ports. Story begins on page 6. (1186X1241-34) Photo: Tim McCabe



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Scientists at this Savannah, GA, lab go a long way to keep insects out of harvested crops.

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Its essential role in human health is accepted, but the amount needed in the daily diet is not yet clear.

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Strawberry Clones Frozen in Time

Consumers in the 21st century could be eating today's superior, virus-free strawberries even if disease, drought, or other disasters wipe out future strawberry crop plants, according to a USDA Agricultural Research Service scientist.

A 100-year experiment to preserve plant tissue will show whether gene-carrying shoot tips of strawberry plants can be frozen in liquid nitrogen and safely thawed to clone new plants.

"I believe this is the first U.S. experiment of this length specifically designed to save plant tissue containing valuable genetic material," says Harry B. Lagerstedt, an ARS horticulturist in Corvallis, OR.

Ultracold freezing, called cryopreservation, has a problem: how to freeze and thaw frozen plant tissues properly without destroying them. Through experimentation, ARS scientists have achieved a 90-percent success rate in freezing strawberry tissues, thawing them, and then growing them into full-size plants.

"Now we are attempting to freeze and thaw raspberries and blueberries," says Lagerstedt, who is research leader for the agency's National Clonal Germplasm Repository in Corvallis.

Scientists there grow, preserve, and study berry crops, pears, filberts, hops, and mint. Other methods used to preserve living plants at the facility besides cryopreservation include growing them in the field, in pots inside insect-proof greenhouses, and in nutrient solutions in laboratory dishes.

Lagerstedt says scientists will monitor the experiment over the next 100 years. The strawberry shoot tips will be removed from the liquid nitrogen after 5, 10, 25, 50, 75, and 100 years, grown into whole plants,

and checked for possible changes resulting from gene defects.

Growing tips of virus-free strawberry clones were prepared for freezing by putting them in a cocktail of polyethylene glycol (an antifreeze), glucose, and dimethylsulfoxide.

Then, vials containing these tiny growing tips—one-fiftieth of an inch across—were placed in a small, box-like freezing chamber. Next, a programmable freezer injected liquid nitrogen into the chamber until the temperature was gradually reduced to minus 40 °F.

Finally, the tips were plunged into a 40-quart vacuum bottle containing the liquid nitrogen at minus 320 °F.

As a backup to this experiment, Lagerstedt's colleagues at the agency's National Seed Storage Laboratory in Fort Collins, CO, will receive a duplicate of the Corvallis experiment.

The beauty of using cryopreservation, says Lagerstedt, is that it is not subject to mechanical breakdown or power failure because there are no moving parts or electrical devices. The only requirement is that more liquid nitrogen be added as needed.—By **Howard Sherman**, ARS.

Harry B. Lagerstedt is at the USDA-ARS National Clonal Germplasm Repository in Corvallis, OR 97331. ■

A True Elm Pioneer

Four elm trees grown from cells stripped of their walls offer hope to genetic engineers who want to infuse the American elm with resistance to Dutch elm disease.

These four plants, now 3 to 4 feet tall, may be the first woody plants to be grown from protoplasts (single cells with their walls removed).

Subhash C. Domir, a plant physiologist with the USDA Agricul-

tural Research Service in Delaware, OH, began his experiment with tissue from leaves of Pioneer elm, a new resistant European-Asian hybrid. Domir used callus tissue, an undifferentiated tissue that forms over wounds in plants. He added a mixture of enzymes to dissolve the walls of the tissue's cells. Then he put the tissue in a centrifuge to remove the debris formed by the enzymes and the cell walls. Certain chemicals in the mixture kept the protoplasts intact.

Then the protoplasts were put in media containing vitamins, sugars, and growth regulators. They first grew new cell walls and then began dividing. The resulting tissue grew into plant shoots, and eventually the plants formed roots. The whole process took 4 to 6 months.

Domir's work was done in cooperation with the Department of Horticulture, Ohio State University, in Columbus.

"Growing protoplasts into complete plants is essential to the type of genetic engineering we want to do," Domir says. "We intend to fuse protoplasts from Pioneer with the American elm."

Protoplast fusion, a chemical bonding of material from two cells, offers a way to do in the lab what is impossible in nature: Merge the genes of two incompatible elms.

The American elm can't be crossed with Pioneer by normal plant breeding because the American has double the number of chromosomes of European and Asian elms.

To date, no one has ever found an American elm with Dutch elm disease resistance that matches the resistance possessed by Pioneer and many other European and Asian elms.

Although hundreds of thousands to maybe millions of American elms are alive and healthy, scientists believe it is mostly by chance rather than a built-in resistance to the disease.—By **Betty Solomon**, ARS.

Subhash C. Domir is at the USDA-ARS Nursery Crops Research, 359 Main Rd., Delaware, OH 43015. ■



Several varieties of mesquite pods.
(0586X604-2)

Mesquite Pods Into Nutritious Foods

Mesquite trees—a range pest sometimes used to charcoal-grill steaks at trendy American restaurants—produce bean pods that a new process can turn into nutrient-rich foods.

“Even though mesquite has been used as a food source for hundreds of years, the bean pods are currently harvested from wild plants only on a very limited basis,” says Robert Becker, a USDA Agricultural Research Service chemist at Albany, CA.

A simple, automated procedure, developed by Becker and colleagues, converts the dried mesquite pods into a high-protein, sweet-tasting flour and a gum that can be used as a natural thickening additive in foods. Standard food-processing equipment can be used.

For flour, whole pods are ground with a disk mill, which produces a mixture of seeds and flour. The mixture is then sifted to separate the two components.

It's the seeds that contain the gum—a thin, white film that lines the inside of the hard, brown seed coat. To extract gum, seeds are split

and soaked in an alkali solution. The solution, after being neutralized, is sprayed through a fine-mist nozzle into a heated chamber, where it dries as a fine powder of edible gum. This spray-drying is the same process that converts fresh milk into powdered.

Analyses at the ARS Western Research Center, Albany, CA, showed that the natural gum in mesquite pods is better than the guar gum U.S. food processors now import to use as a natural thickener in ice cream, salad dressings, puddings, and other foods.

A food-processing plant in Chihuahua City, Mexico, is now using Becker's method—with minor modifications—to produce a sweet, high-energy snack food from compressed mesquite flour.

Currently, pods are picked by hand, limiting mesquite's use as a crop to countries where labor costs are lower than in the United States.

In the American Southwest, mesquite infests millions of acres. In some places it forms dense, thorny thickets and crowds out grasses that are needed to feed cattle.

Scientists in Chile and Mexico cooperated with Becker in the mesquite pod research, which was funded in part by the U.S. International Development Cooperation Agency.—By **Marcia Wood**, ARS.

Robert Becker is at the USDA-ARS Western Research Center, 800 Buchanan St., Albany, CA 94710. ■

Carbon Dioxide Makes Heat Therapy Work

Scientists can now propagate healthy blueberry and raspberry plants from virus-infected stock by treating it with heat and carbon dioxide.

“We grow plants at 100°F Fahrenheit, which makes them develop faster than the virus can spread,” says ARS plant pathologist Richard H. Converse. “Then, we

take cuttings of the new growth—less than an inch long—and raise them into full-sized, virus-free plants.”

But in this race to outdistance the virus, some plant species are not able to take the heat. Some even die.

“Chemical reactions double for every 14°F rise in temperature,” Converse says. “So, if you try to grow a plant at 100°F that was originally growing at 86°F, it will double its respiration rate. The danger is that the plant growing at the higher temperature could soon exhaust its stored food reserves much like a runner who runs too hard and tires.”

Adding carbon dioxide increases the rate of photosynthesis in plants, which increases the plant's food reserves.

Converse's findings on blueberries and raspberries are based on earlier research Australian scientists did on grapes.

The Australians had discovered that they could successfully grow plants in growth chambers at continuously high temperatures if the slight amount of carbon dioxide normally present in the air (about 350 ppm) was increased to 1,200 ppm.

“What carbon dioxide does,” says Converse, “is to make the heat treatment safe. It allows some plants to grow at temperatures they would otherwise not survive and allows other plants to grow for longer periods at 100°F.”

One problem with the process, says Converse, is that the longer plants are exposed to heat the greater the mutation rate. So, resulting clones should be closely examined for trueness to horticultural type.—By **Howard Sherman**, ARS.

Richard H. Converse is at the USDA-ARS Horticultural Crops Research Laboratory, 3420 Southwest Orchard St., Corvallis, OR 97330.

[A technical paper covering this subject, by R.H. Converse and R.A. George, will appear in early 1987 in volume 71 of the journal Plant Disease.] ■

Insect Control at Sea



Entomologist James Leesch (left) and biological technician Dennis Sukkestad make temperature readings of wood chip shipment. (1186X1242-2)

Bugs invading a bag of kitchen flour or eating your favorite woolen sweater are bad enough, but imagine insects infesting a shipload of grain where a single shipment is big enough to fill a football field 25 feet deep.

That much grain—about a million bushels—can be aboard a typical bulk-cargo ship heading for a foreign market. If the grain is unprotected, millions of beetles, moths, and weevils can be eating “end zone to end zone” by the time it arrives.

Grain from many different farmers is mingled as it moves from farm to export elevator. Some of these farmers protect their grain by drying it to hold down insects, fumigating with chemicals, and keeping storage temperatures as low as possible so insects can't develop.

Between 3 and 10 percent of all stored grain is lost because of insects, Agricultural Research Service scientists say.

Other farmers aren't so careful; consequently, shippers may inadvertently mix insect-ridden grain with the clean when loading a ship's hold.

If that happens, the whole load can be infested by the time the ship completes its 2- or 3-week trip to Egypt, the Soviet Union, China, or another foreign market. These countries pay far less for infested grain or may even reject it.

Problems like this damage the reputation of American grain quality at a time when the U.S. share of world markets for wheat and coarse grains has been dropping. According to U.S. Department of Agriculture statistics, American grain accounted for 36 percent of the world grain trade in 1985, down from a 58 percent share five years earlier.

At the USDA Agricultural Research Service Stored-Product Insects Research and Development Laboratory in Savannah, GA, 23 scientists focus on insects like the Indianmeal moth, rice weevil, and lesser grain borer. These and other pests infest grain,

Photo: Tim McCabe

flour, rice, cereals, peanuts, woolen fabrics, and other products in storage.

They gain a foothold in any number of ways. Some, like the Indianmeal moth, slip into a warehouse and enter peanuts through damaged shells. Others, like the lesser grain borer or cigarette beetle, can bore through a cardboard cereal box to find food.

Although insects are a problem while a plant is growing, they may do as much or even more damage after a crop is harvested. Nationwide figures vary, but ARS scientists estimate that between 3 and 10 percent of stored grain is lost because of insects. One study by University of Minnesota scientists in 1985 estimated that in Minnesota alone, insects cause \$352 million in losses each year to grain and cereals after they are harvested.

"That gives you some idea of what we're up against," says entomologist Robert Davis, director of the Savannah lab. "We've come a long way and have developed new ways to control these insects. But we're still gaining a lot of basic knowledge about them—how they live, reproduce, and multiply—so that we can find new ways to control them."

Eliminating these ubiquitous pests is impractical and probably isn't even possible, Davis says, so the name of the game is control—minimizing insect damage and holding down losses.

That's the approach the lab took when it confronted the problem of protecting grain on board ship.

In the early 1970's, if shippers found infested grain during loading, they stopped and fumigated aboard ship for 10 or 12 hours. They used an old fumigant called 80-20—later found to be carcinogenic and banned. Once the grain was fumigated, inspectors routinely entered the hold to check the load.

That not only exposed inspectors to the dangerous fumigant, but the 10- or 12-hour period was only long enough to kill adult insects.

"Not only was it unsafe for inspectors," Davis says, "but the fumigation procedures were ineffective because the immature insects would grow aboard ship. We needed a way to wipe out in-

festations with little or no risk to workers."

So the scientists, working with grain shippers at the nearby Port of Savannah, developed a procedure to use a new fumigant, phosphine, to treat grain. In 1977, USDA's Federal Grain Inspection Service approved phosphine for use aboard ship—or in transit—for loose grain loaded into airtight holds.

Phosphine, a gas composed of hydrogen and phosphorus, is heavier than air. It forms when moisture in the air spaces between grain kernels reacts with a solid chemical, aluminum phosphide.

The aluminum phosphide is placed in the ship's hold primarily in two ways. One is to drop tablets the size of a quarter through 5-foot-long pipes that are pushed into the grain. The pipes

"Eliminating stored grain pests probably isn't possible, so the name of the game is control—minimizing damage to hold down losses."

—Robert Davis, ARS entomologist

are then pulled out, leaving the tablets to release phosphine which seeps down through the grain.

Shippers also add aluminum phosphide by using bag blankets. These are about a foot wide by 40 feet long and have 100 pockets sewn into them, each containing 34 grams of aluminum phosphide. These blankets are rolled onto the surface of the grain, and the gas escapes from the pockets.

Phosphine is dangerous to humans if inhaled but is safe if used properly, and it does not harm the grain itself, Davis says. Phosphine gas and grain are sucked from the hold by huge vacuum hoses, and the gas dissipates harmlessly into the atmosphere.

"It's more effective than the previous method and is far safer for inspectors and workers," Davis says. "Since 1975, more than 4,500 ships have sailed from U.S. ports with one or more holds being fumigated with phosphine. The savings to the grain industry must be in the hundreds of millions of dollars."

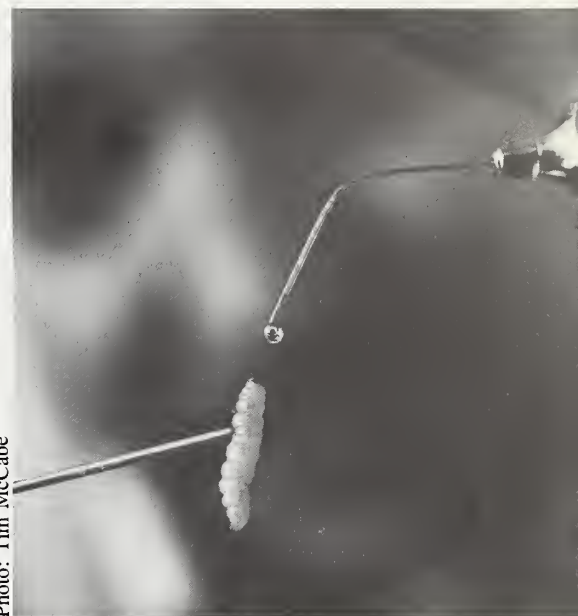


Photo: Tim McCabe

Entomologist Larry Zettler places a droplet of malathion on an Indianmeal moth larva during tests to determine the larva's resistance. (1186X1254-15)

Today, research is continuing to improve this procedure by making sure the fumigant reaches the bottom of the ship's hold—an average of 50 feet but some as deep as 88 feet. Last year, scientists used long rolls of 4-inch plastic pipe—similar to pipe used in a septic drainfield—to distribute gas in grain 80 feet deep.

Davis says the lab's scientists are working on transferring the technology from grain to other commodities, such as flour and products shipped in bags.

One of the most recent efforts to try this technology on a new commodity came in August 1986. Wood chips for paper pulp, a vital part of Georgia's \$8 billion timber industry, were banned from Sweden in February 1986 because they contained the pinewood nematode. Swedish officials feared that the nematode could spread pine wilt disease to Sweden's forests.

To counteract this threat, entomologist James G. Leesch and chemist Richard A. Simonaitis oversaw the layering of the aluminum phosphide into the wood chips loaded on a ship. They then accompanied the 22,000-ton load on its 25-day trip to Sweden.

Preliminary results in October showed that of 70 samples of wood



Stored peanuts are collected by entomologist John Brower to determine the damage from the Indianmeal moth larva and almond moth larva. (1186X1244-25)



Almond moth larva and damaged peanut. (1186X1246-11)

Photo: Tim McCabe

chips taken, 66 had no live nematodes, and 3 had extremely low levels. One had high levels, but Leesch said that may have been in an isolated pocket of chips and not exposed to the fumigant.

"Overall, though, we estimate that the fumigant killed about 98 percent of the nematodes, and we consider that a success," Leesch says. As of mid-November, Sweden was accepting wood chips treated with phosphine pending further tests.

Carbon Dioxide An Alternative Fumigant

Phosphine and methyl bromide are the common chemical fumigants used today, but scientists say insects are developing resistance to them. That has prompted a search for alternatives such as carbon dioxide and ozone.

Entomologist Edward G. Jay has been testing carbon dioxide as a grain treatment and says a large grain elevator in Texas and several rice processors in Texas, Louisiana, Arkansas, and California now treat a large portion of their products with carbon dioxide.

Typically, carbon dioxide gas is

forced through grain, displacing air and killing insects by drying them out and stopping their respiration. It leaves no residue on the grain and is available at roughly the same cost as other conventional chemical fumigants, Jay says.

Normally, grain at 80°F must be exposed to carbon dioxide for 4 to 5 days to kill all life stages of insects, but Jay recently found that at 90 to 100°F, exposure time can be reduced from 1 to 2 days. Corn and sorghum, harvested in late summer or fall in the southern United States, are often that temperature when taken from the field.

Ozone, a gas normally present in the stratosphere, is formed near the earth's surface when sunlight reacts with oxygen and air pollutants in the atmosphere. Entomologist E. Wayne Tilton says ozone, which can damage plants even at low levels, also has a variety of beneficial uses—to sterilize hospital equipment and as a substitute for chlorine in water treatment plants in Europe, for example.

He says it kills the confused flour beetle, lesser grain borer, Indianmeal moth, and rice weevil and does not affect germination of wheat, corn, or peanuts. He also says ozone poses no pollution problems. "If you pass it through a simple charcoal filter, it comes out as plain oxygen," Tilton says.

Carbon dioxide and ozone may provide a necessary alternative to fumigants now in use, because insects are becoming more resistant to chemicals. This has been particularly bad for the Georgia peanut industry, because the three major pests of stored peanuts—Indianmeal and almond moths and the red flour beetle—all show resistance to malathion, a commonly used insecticide.

Entomologist J. Larry Zettler has been capturing these insects from peanut warehouses and testing them for resistance to malathion. He says the insects, found in Florida, Alabama, and Georgia, are highly resistant to malathion, and that peanut growers in the Southeast are becoming concerned.

Biological Alternatives to Fumigation

Tiny parasitic wasps that kill the moths may be a way to safeguard some

Photo: Tim McCabe

harvested crops. Entomologist John H. Brower has been studying these parasites, *Trichogramma* and *Bracon*, to kill pests in stored peanuts.

Trichogramma strikes by laying one egg inside each moth egg; *Bracon* can lay up to 10 eggs on the surface of the moth larvae. When the parasites' eggs hatch, the larvae feed on and kill the moth eggs or larvae.

Although *Trichogramma* and *Bracon* are wasps, people have no need to fear them because they don't sting humans. *Trichogramma* doesn't sting insects, either, but *Bracon* does use its sting to paralyze moth larvae before laying eggs on them.

In a recent 11-week test at Savannah, the wasps used together reduced the Indianmeal moth population by 85 percent and the almond moth by 98 percent.

"If all else fails, a good insect-resistant package is critical for protecting stored foods."

—Henry A. Highland, ARS entomologist

Brower says the wasps work best if they can reduce the moth population in a warehouse before peanuts are brought in for storage. Releases must be continued after the warehouse is filled to prevent reinfestation.

Brower says that by late 1987, scientists at the lab hope to conduct large-scale commercial tests using this method. He says the parasites could also be used to control the moths in other stored products such as corn, dried fruits, and nut meats.

If chemicals or other insects aren't the answer, dill seed, lemon peel oil, and red peppers may be. Savannah chemist Helen C.F. Su examines everyday items like these and has identified the ingredients in them that act as nature's own protection against insects.

In her most recent studies, she has found ingredients in dill seed oil that have a long-lasting repellency against confused flour beetles, the most abundant and injurious pest of flour mills in the United States. And a chemical in lemon peel oil repels cowpea and rice

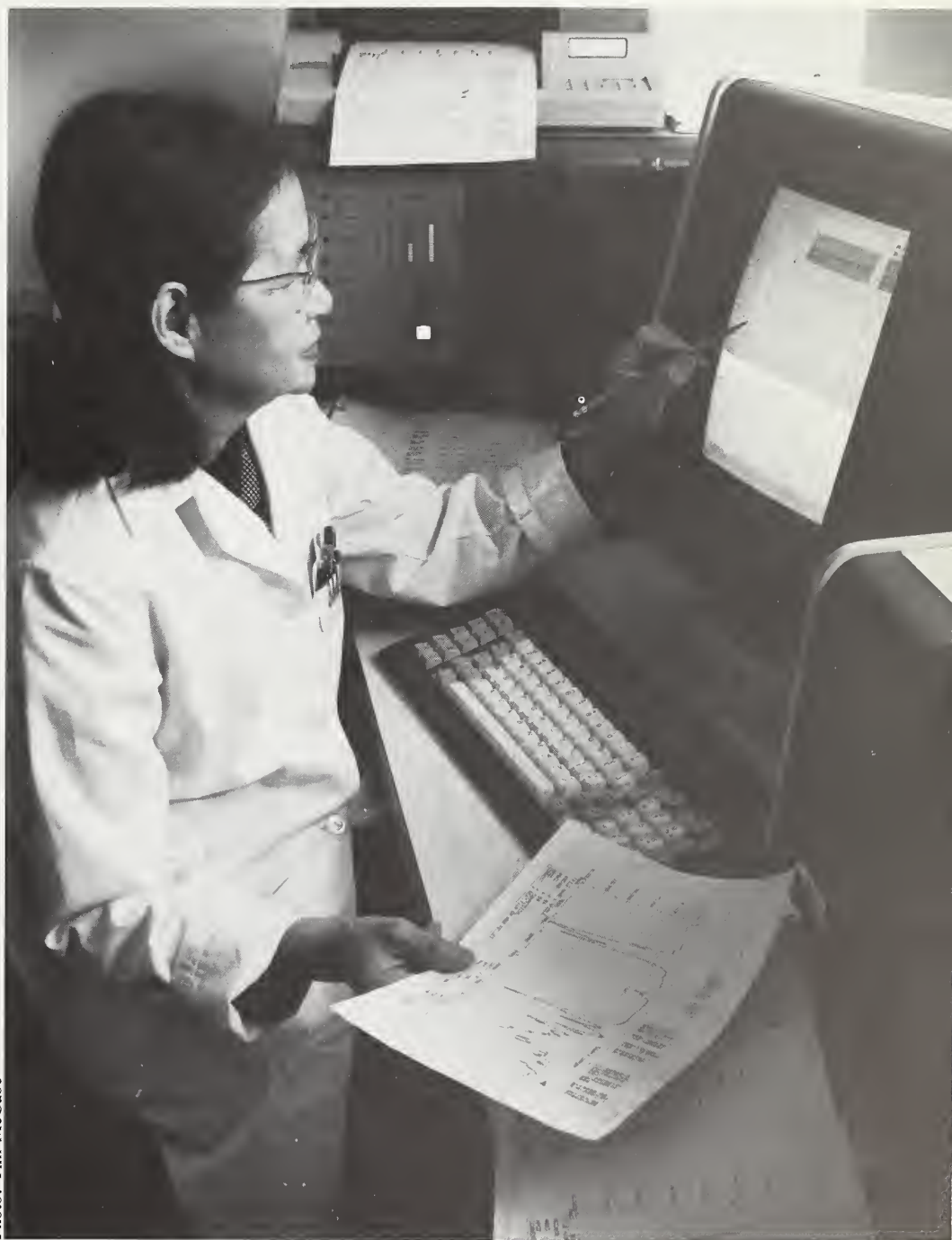


Photo: Tim McCabe

Using an infrared spectrophotometer, chemist Helen Su probes for the chemicals in dill seed that help protect it from insects. (1186X1261-23)

weevils, which are particularly damaging in warm climates.

"We identify the repellent chemical, find out how it works, and provide the information to industry that could then develop it for practical use," Su says.

If all else fails, a good insect-resistant package is critical for protecting stored products, says entomologist Henry A. Highland. Good packaging is needed to keep out insect "invaders" and "penetrators." The invaders get into products through holes and cracks,



Entomologist Roy Bry (left) and technician Joe Lang spray a woolen sample with a pyrethroid spray. (1186X1257-11)

while penetrators bore their way through packaging.

Highland tested a new carton, developed by industry, that is coated with polyethylene and heat-sealed and has a laminated top of foil and plastic. He says it may become the state-of-the-art for packaging cereals, biscuit and cake mixes, flours, raisins, and other dried fruits that insects like.

In tests last year, Highland compared this new container with conventional cardboard containers. Over a 24-week period, only 14 percent of the new cartons filled with raisins were infested; 76.5 percent of the conventional cartons were infested. Using biscuit mix, only 5.5 percent of the new cartons were infested; all of the old cartons were.

As another defense, Highland and entomologist Michael A. Mullen are testing an insect growth regulator, methoprene, by applying it to packaging. In preliminary tests, methoprene has controlled the red flour beetle by stopping it from reproducing.



In studies to determine the resistance of commercial polyethylene and polyester packaging to insects, entomologists Henry Highland (right) and Michael Mullen examine packed peanuts that have been subjected to five species of insects. (1186X1249-22)

Methoprene is currently registered for use on stored tobacco against the cigarette beetle.

Keeping moths out of woolen products isn't easy, either—and hasn't been since antiquity, according to entomologist Roy E. Bry. Archeologists rarely find woolen items because wool is prone to attack by insects that like its keratin, a fibrous protein that moths can digest. Moths cause damage when they lay eggs on woolen textiles and the larvae eat wool for its keratin.

To stop them, Bry says, the lab has tested pyrethroid insecticides that provide alternatives to chemicals such as DDT that have been banned for years. Originally, scientists thought pyrethroid sprays would lose their effect after about 6 months. But Bry's tests show that these sprays provide protection for up to 6 years.

Several of these pyrethroids are available commercially, and they may give better protection than the smelly mothballs that abound in storage closets.

Still under study at the lab are a number of other projects aimed at gaining a greater understanding of stored-product insects, including: how moisture, temperature, and other factors affect their reproduction and survival; learning more about how moths reproduce to see if they can be prevented from laying eggs or fertilizing them; and studying substances in grain that inhibit insects from digesting it.—By Sean Adams, ARS.

Scientists mentioned in this article are at the USDA-ARS Stored-Product Insects Research and Development Laboratory, P.O. Box 22909, Savannah, GA 31403. ■

Photo: Tim McCabe

Photo: Tim McCabe

Selenium: Finding the Delicate Balance

Too little of it leads to the degeneration of heart muscle in children. Too much of it produces a garlicky breath, and extreme levels can cause the loss of hair and nails. How much selenium is the right amount?

USDA's Orville A. Levander has devoted most of his professional career to answering that question. Levander, a chemist with the Agricultural Research Service Vitamin and Mineral Nutrition Laboratory, is based at the Beltsville (Maryland) Human Nutrition Research Center.

Fortunately, he says, North Americans get adequate selenium in their diets because "a lot of our food and feed crops are grown in selenium-rich soils. And our nationwide food distribution system fills any gaps." But there are areas around the world where the people exist on foods containing little or no selenium. Levander's search for the right amount has taken him to such pockets in Finland, China, and New Zealand.

"Millions of children living in the selenium-deficient areas of China are at risk of losing heart muscle."

—Orville A. Levander, ARS chemist

"Millions of children living in the selenium-deficient areas of China are at risk of losing heart muscle," he says, "but only a small percentage ultimately develop the condition known as Keshan disease. Giving a small selenium supplement to these children can prevent the disease altogether."

Now, under a National Cancer Institute study, he is looking for indications of too much selenium among people in a selenium-rich section of China and in South Dakota where animals have been poisoned by high levels in range plants.

In its role as an essential nutrient for humans, selenium becomes part of the enzyme glutathione peroxidase, which ranks with vitamins E, A, and C as an antioxidant. Like vitamin E, glutathione peroxidase protects the unsaturated fatty acids in cell membranes

from being oxidized. (A similar oxidation reaction turns butter rancid.)

In fact, says Levander, vitamin E can partially cover for an inadequate selenium intake and vice versa, although the two nutrients probably work in different ways. "Some doctors and nutritionists advocate increasing polyunsaturated fats in our diet but that increases a person's requirement for selenium and vitamin E."

Levander says international studies underline the pitfalls in basing Recommended Dietary Allowances on balance studies. A person is said to be in balance when the daily intake of selenium, or any other nutrient, equals the amount excreted. But Chinese men living in a selenium-deficient area need only 10 micrograms a day to maintain their body stores of selenium, whereas U.S. men need 80 micrograms. A microgram is one-millionth of a gram.

"You can get a very large difference depending on what population you study and what their historical selenium intake has been," he says. According to balance studies, women in the United States need about 60 micrograms of selenium a day to maintain their body stores. For both sexes, the "balance requirement" comes to about 1 microgram per kilogram of body weight. "Because most of the body's stored selenium is in muscle, large men require more than small men or women."

As the selenium expert on the National Academy of Sciences' Recommended Dietary Allowance Committee in 1985, Levander relied heavily on the work of scientists in China. By supplementing men living in the extremely deficient areas with increasing amounts of selenium, the Chinese scientists determined how much of the mineral was needed to push the activity of glutathione peroxidase to its limit.

Levander incorporated the appropriate safety factors and corrections for body weight and arrived at recommendations that "were surprisingly close to the results of the U.S. balance studies."

The Academy failed to reach a consensus on the 1985 revisions as a whole, so, until the next revisions come out in 1990, selenium still has a



Daisy Wills places a special high selenium diet in a test rat's cage during studies to determine selenium retention. (1186X1268-23)

suggested "safe and adequate" range of 50 to 200 micrograms, but no official RDA.

Some nutrition researchers now emphasize reducing the risk of chronic diseases such as heart disease and cancer in formulating dietary recommendations, Levander says. That raises the problem of toxicity for certain nutrients.

For example, some populations with a high-selenium intake reportedly have lower rates of breast and colon cancer, he says, "but many other factors could be responsible." In very large doses—well above the 200 micrograms deemed safe—the mineral protects laboratory animals against certain chemical carcinogens. It has also proved effective against a spontaneous mammary tumor in mice, says Levander, adding that cancer is not due to selenium deficiency.

"We really don't have a clue as to how selenium might be protective. The findings in numerous animal studies strongly suggest such an effect," he

says, "but some recent studies contradict those findings." Such studies have not been done in humans, however, "because the doses are so large they could be toxic."

As for selenium's alleged ability to reduce risk of heart disease, Levander says the evidence is not very solid. "The latest findings I've seen suggest there may be other factors in the diet that are having the positive effect."

"We don't have very good indicators for selenium toxicity." People who accidentally take large amounts of selenium lose their hair and nails and may experience a tingling or loss of feeling in the fingertips, indicating some effect on the nervous system. But these symptoms occur well beyond a safe level, says Levander. "A lot of changes must have occurred in body chemistry before you start seeing hair and nail loss."

People who work in ore smelting or electronics industries can also be accidentally exposed to high levels of selenium, he says. "Workers are reassigned to other duties if they develop a garlicky breath." But again, "that symptom probably occurs beyond the limit of desirable exposure."

In the South Dakota study, Levander is looking for early warning signs of too much selenium in the urine. He says that animals exposed to high doses of selenium increase their excretion of an unusual selenium-containing compound closely related to the substance that causes the garlicky breath. Its increase in the urine may precede the body's dumping of excess selenium through the lungs.

Levander's international research on this mineral has turned up some interesting quirks. The human body discriminates between both the form and the source of selenium, he says. It distinguishes between selenium salts—inorganic forms of selenium—and the organic forms found in foods. "The inorganic forms are not stored in the tissues particularly well.

People who accidentally take large amounts of selenium lose their hair and nails and may experience a tingling or loss of feeling in the fingertips.

"Organic forms, however, tend to accumulate in the body. This can be a double-edged sword. Organic selenium could be used to increase the selenium level in a deficient population more quickly. But because it accumulates, there could be a dangerous buildup in the tissues."

"Once zinc is absorbed (into the bloodstream), zinc is zinc, and the body doesn't appear to discriminate between forms. With selenium, however, there's a big difference in how the body treats different forms."

This is also true for different sources of selenium. For example, the body absorbs zinc and iron better from animal sources than from plant sources. "That's not the case with selenium; in some instances the opposite occurs," says Levander. "Selenium from fish

can be relatively unavailable, whereas the mineral is readily available from wheat or—in its inorganic form—sodium selenate."

Availability, however, does not just depend on how much is actually absorbed, Levander explains, but also on how well the body uses what gets into the blood. "In general, people absorb a whopping 80 percent or more of the selenium they ingest. That's amazing when compared with iron absorption which is about 10 percent." It turns out that the kidneys control body levels of selenium, whereas the intestine regulates body levels of other trace elements such as iron, zinc, and copper.

Levander says these findings alerted the nutrition community that "our whole concept of bioavailability may need some reevaluation. In the past, people have equated bioavailability with absorption. In other words, if the body can absorb a nutrient, it seems to be able to use it pretty efficiently. But, with selenium compounds, we're faced with quite a different situation. Absorption of selenium is not a problem. It's this metabolic conversion to the biologically active form that may be the limiting factor."

For his work in uncovering these eccentricities of selenium, Levander received one of the American Institute of Nutrition's highest awards in 1985.—By **Judy McBride, ARS**

Orville A. Levander is at the USDA-ARS Vitamin and Mineral Nutrition Laboratory, Bldg. 307, Room 220B, Beltsville Human Nutrition Research Center, Beltsville, MD 20705. ■

Selenium Balance Critical for Livestock, Too

Ranchers grazing livestock on western rangeland where soils contain high levels of selenium may be losing millions of dollars because of lowered production from their animals.

"Many livestock losses are subtle and relate to reproduction," says Lynn F. James, research leader of the ARS Poisonous Plant Research Laboratory in Logan, UT. Although usually not fatal, selenium may "suppress the outward signs of the cows' estrous or fertile cy-

cle, which in turn delays breeding."

One selenium-accumulating plant found on western ranges, *Astragalus bisulcatus*, is also a selenium indicator. Although livestock normally won't eat the plant, its presence means palatable grasses growing in the area are probably high in selenium. This could be a natural warning sign for ranchers: If this plant flourishes, your animals won't!

Scientists at the Poisonous Plant Lab are also studying the toxic effects

of selenium on pigs and how this may relate to other livestock.

Why pigs? "They're easy to work with and provide good livestock models," says James.

The researchers have shown that pigs on a high selenium diet can develop a form of polio that paralyzes the animal's hind legs. These pigs were also thinner, smaller, and had less hair than pigs on normal diets.—By **Howard Sherman, ARS. ■**

Wheat Hardness Test May Aid Exports, Wheat Quality

When ground one by one, wheat grains give off vibrations that scientists can measure to test for hardness, a key to grading and pricing this major crop.

The measuring device invented by engineers David R. Massie and Karl H. Norris of USDA's Agricultural Research Service electronically registers grain vibrations produced by grinding. A computer linked to the device prints hardness scores on a readout tape.

"Hard grains grind slightly louder than soft ones," says Norris. "The simplicity of the device could make it especially valuable to grain inspectors." "If adopted nationally, it could eventually help raise both the quality of domestic wheat flour and the value of our wheat exports."

Hard wheats bring a higher price for flour used to make bread, while soft wheats, more suitable for cookie and cake flour, generally sell for less.

"Wheat breeders have told us that a quick measure of wheat hardness will help them evaluate new varieties," Norris says. "This would help seed companies, too, and be even better for farmers who will know exactly what they are planting and marketing."

Massie and Norris say they stopped working on an expensive laser-beam method to test hardness and switched to vibration detection when they clearly heard differences in grinding sounds of hard and soft grains.

A sample of grain can be tested by pouring it into a feeder trough that sets on top of a 6-inch-diameter cylinder. The electrically operated device vibrates the grains in the trough so they fall one at a time from the edge of the trough into the cylinder. There, a high-speed impeller (rotor) hurls each grain against an outer ring, which is coated with Carborundum abrasive to give it a rough surface. The impact crushes each grain.

USDA's Federal Grain Inspection Service is testing the latest grinder model for possible use in wheat grading. This agency sets guidelines for agricultural commodity graders and issues licenses to grain inspectors. Over 3 million grain inspections are conducted at grain elevators each year.

Several years ago, Norris developed another device to test the protein



Photo: Tim McCabe

In his laboratory, David Massie conducts tests with an early version of the grinding cylinder used to determine hardness of wheat grains. (0886X995-12)

and other nutrient values of grains and oilseeds. This near-infrared reflectance (NIR) instrument was adopted by the grain inspection agency. Over 4,000 commercial NIR devices are in use in this country—by grain elevator operators, food processors, and others—and

over 7,000 are in use worldwide.—By **Stephen Berberich, ARS.**

David R. Massie and Karl H. Norris are at the USDA-ARS Instrumentation Research Laboratory, Bldg. 002, Beltsville Agricultural Research Center-West, Beltsville, MD 20705. ■

TECHNOLOGY

Underground Channels Mapped by Radar



Geologist Loris Asmussen reviews a soil density profile chart produced by the radar as it moves over a test area (background). (0786X824-9)

Ground-penetrating radar that can detect hidden water channels is helping U.S. Department of Agriculture researchers predict what happens to pesticides after they are applied to crops.

"Our research is like doing book-keeping for an ecosystem. We establish a budget for water, pesticides, and fertilizer use on a watershed, then try to account for how much was spent and where," says Ralph A. Leonard, soil

scientist with the USDA Agricultural Research Service.

"Radar's role is vital in accounting for agrichemical movement that can't be seen," says Leonard, who is a member of a research team at the agency's Southeast Watershed Research Laboratory in Tifton, GA.

One of Leonard's uses for radar is as a surveying tool for charting topographic maps, not of land surfaces but of underground features. As the trailer-mounted unit is towed across a field, a series of echoes from radar signals bounce from the soil at various depths to give researchers clues to where and how chemicals are likely to move underground.

"Radar gives scientists underground data that they can use in computer models to help devise better ways of keeping agrichemicals out of groundwater," says David A. Farrell, the agency's national program leader for groundwater research.

"Our studies at Tifton and other locations are expected to yield new answers for protecting groundwater supplies," Farrell says.

At Tifton, the radar work is pinpointing the depths at which changes, such as different densities, occur in soil.

"Recording changes in soil density on a map lets us make a profile of the contour of an impervious soil layer. Its ups and downs are much like slopes, ridges, and valleys," Leonard says.

Watertight soil layers can form channels that intercept water and associated chemicals from beneath a crop's root zone and direct to either an aquifer or a body of water. Aquifers are reservoirs for the groundwater that supplies one-half the nation's drinking water.

When such a channel lies above the main aquifer it is called a perched aquifer. On Georgia's coastal plain, a perched aquifer may be only a few feet below the surface, while the main aquifer may be 60 to several hundred feet down.

A perched aquifer is just one thing to consider when tracking the movement of water in complex and out-of-sight groundwater systems, Leonard says.

Photo: Tim McCabe

TECHNOLOGY

Robot Chemist Assesses Nutrients in Today's Foods

Among others are the direction and rate of waterflow and location and thickness of the main aquifer, its geologic formation, and its ability to store and transport water. Radar helps in obtaining this information.

Leonard's research team is unraveling the intricacies of pesticide movement across and beneath field-sized watersheds. The land, which supports woods as well as field crops, is dotted by springs and ponds and crossed by sluggish streams.

Leonard says that besides pinpointing the location and depth of perched and main aquifers, radar can help:

- Determine where water flowing laterally in a perched aquifer eventually goes, whether to a main aquifer, a spring, a pond, or a stream.

- Select the best locations to place observation wells for monitoring fluctuations in the level of the water table or for collecting water samples for chemical analysis.

- Measure how much water is in a pond by sending signals from a boat-carried unit to the pond bottom.

"Radar can help in solving special problems of tracking groundwater movement in regions underlain by limestone," Leonard says. "For example, its signals may pick up fractures or large openings in limestone through which water pours as through a pipe."

It can also probe sinkholes formed when limestone dissolves and collapses. These sinkholes often fill with drainage water, becoming surface lakes. Radar can help tell whether the water stays in the lake or enters an aquifer.

Leonard's research team is developing data for GLEAMS, a computer model that predicts potential effects of pesticides on groundwater. The model, whose full name is Groundwater Loading Effects of Agricultural Management Systems, is under test by the research agency and the USDA Soil Conservation Service.

GLEAMS will also be tested in a groundwater research project in cooperation with the U.S. Geological Survey.—By **Russell Kaniuka, ARS.**

Ralph A. Leonard is at the USDA-ARS Southeast Watershed Research Laboratory, P.O. Box 946, Tifton, GA 31793. ■

A tabletop robot is now employed at the USDA Agricultural Research Service Nutrient Composition Laboratory in Beltsville, MD, helping chemists assess the vitamin content of foods commonly eaten in the United States. In just 15 minutes, the 2-foot-tall mechanical assistant unscrews a cap from a test tube, adds acid to the dissolved food sample, screws the cap back on, places the tube in a shaker, then transfers it into a centrifuge, and finally draws a small specimen into a syringe and sends it on its way through a high-performance liquid chromatograph.

Working with the robot, "I can run twice as many food samples in 8 hours," says Darla J. Higgs, who programmed each precise movement of the robot's stainless-steel arm. "It's not that it moves any faster than a person; it just keeps going."

"Our goal is to automate our analytical systems," says Higgs, a physical sciences technician.

The Nutrient Composition Laboratory is charged with developing new technology and improving existing methods for measuring nutrients in foods, according to its head scientist Gary R. Beecher. In addition, he says, "the staff analyzes nutrients for which information is either antiquated or lacking or that have been associated with major health problems such as heart disease or cancer."

According to colleague Joseph T. Vanderslice, the nutrient values for some foods listed in USDA's handbook on food composition are calculated or inferred from measurements of other foods. And the U.S. diet has changed over the years from agricultural commodities to processed foods. "Processing can alter the types and amounts of vitamins and essential minerals," he says.

Higgs says she launched the robotic system on an analysis for vitamin C because the vitamin's instability would test the system's reliability and reproducibility. After adding a chemical stabilizer to the food samples, she found that the vitamin could be analyzed over a 24-hour period without degradation or loss of either of its two active forms.



Photo: Tim McCabe

Darla Higgs programs robot for tests related to vitamin C studies. (1186X1272-16)

"Some of the vitamin C values in the food composition handbook are only for ascorbic acid, while others include dehydroascorbic acid—its other active form," Higgs says.

Analyses for vitamin B-1, which is more stable than vitamin C, also proved to be very reliable and reproducible using the robot.

"It's more consistent," she says, noting that robots don't make the errors a person would make, especially when working 24-hour days.

Robots can also work in total darkness or in cold rooms if the nutrients being analyzed happen to be light sensitive or need to be kept chilled.—By **Judy McBride, ARS.**

Darla J. Higgs, Joseph T. Vanderslice, and Gary R. Beecher are in Building 161, Beltsville Agricultural Research Center-East, Beltsville, MD 20705. ■

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PATENTS

What's That Chewing?

A new listening device can detect chewing and movement sounds of larvae hidden in grapefruit and other fruits amid the din of a packinghouse. Once infested fruit is identified it can be removed before shipping.

The grapefruit rests on membranes similar to those used in doctors' stethoscopes. The membranes, from 1 to 1.5 inches in diameter, sit on top of a plastic tube which channels sound to a microphone for conversion to an electrical signal. The signal is then amplified from its original frequency, 300 hertz or lower, to about 1,000 hertz and filtered so only the desired frequency is relayed to a computer.

At this frequency, sounds are easier to hear and discriminate from the low-frequency rumble found at packinghouses.

With variations in design, this instrument also detects larvae in nuts and grains.

For technical information, contact J.C. Webb, USDA-ARS Insect Biophysics Research, P.O. Box 14565, Gainesville, FL 32604. *Patent Application Serial No. 861,770, "Acoustical Detection of Hidden Insects."* ■

Debitting Citrus Juices

The cost of experimentally debittering citrus juices with bacterial cells drops by using a strain of the bacterium *Corynebacterium fascians* that can be grown without citrus limonoids.

Scientists have been using enzymes from bacteria to convert the bitter limonoids in orange and grapefruit juice to nonbitter compounds. But until now they had to extract limonoids from fruit and add it to growth solutions to induce bacteria to produce cells with the necessary enzymes. Because limonoids are not available commercially, bacterial strains requiring them are more costly to work with.

For technical information, contact Shin Hasegawa at the USDA-ARS Fruit and Vegetable Chemistry Laboratory,

263 South Chester Ave., Pasadena, CA 91106. *Patent No. 4,447,456, "Strain of Corynebacterium fascians and Use Thereof To Reduce Limonoid Bitterness in Citrus Products."* ■

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